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Sequentially and Alternatively Developed Heights for Two Representative Bench Marks: Near Palmdale, California and Along the Bill Williams River, Arizona

by

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1. Menlo Park, CA

This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature.

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INTRODUCTION

This report consists chiefly of 41 tables that both describe and fully document the reconstructions of a series of alternately developed heights based on levelings leading into two representative bench marks in the southwestern United States. One of these marks, 3219, Vincent, California (fig. 1), lies within the area of the Pacific-North American plate boundary; the other, 22Q, Bill Williams River, Arizona (fig. 1), falls within what is believed to be a singularly stable section of southwestern Arizona. Because the levelings that produced these heights were characterized by especially disparate routes with respect to both terrain and climate, the resulting heights provide a test for the existence and magnitude of path-dependent error in geodetic leveling. These two marks were chosen both because of their relative stability with respect to adjacent marks and because their tectonic stability (or instability) can be inferred from the geologic record. Specifically, we can reasonably speculate that 3219 may have sustained measurably significant tectonic displacements during the 20th century, whereas 22Q probably has remained virtually invariant with respect to any fixed datum during the same period.

Bench mark 3219 is a standard Geological Survey iron post stamped "3219" near the Southern Pacific Railroad station at Vincent (U.S. Geological Survey, 1898, p. 392); 22Q is a brass cap stamped "22Q (MWD)" set in a concrete post located in a gully immediately north of the Bill Williams River, Arizona (USC&GS Quad. 34114). 3219 was established by the Geological Survey no later than 1897 (Gannett and Baldwin, 1907, p. 365); 22Q was established by the Metropolitan Water District of southern California in advance of the 1931 control surveys along the projected route of the Colorado River Aqueduct.

REFERENCE MARK

All of the heights referred to in this report are reconstructed with respect to the record height of 3.3921 m for bench mark Tidal 8, San Pedro (fig. 1); it is this value which has been added to the sum of observed elevation differences in each table.

Tidal 8 is one of several tidal bench marks adjacent to the primary San Pedro tide station; the history of this station with respect to other California tide stations indicates that Tidal 8 has been characterized by relatively positive movement with respect to mean sea-level (Hicks and Crosby, 1974). Accordingly, successively determined heights for any bench mark with respect to the record height of Tidal 8 are biased slightly toward apparent subsidence. Because there is no record of Tidal 8 having existed prior to 1926, earlier heights cannot be referred directly to this mark, but rather are based on extrapolated values from various nearby bench marks and a tie to a local sea-level datum. Detailed procedures used in reconstructions of pre-1926 heights are set forth in the footnotes accompanying Tables 1, 4, and 38.

THE RECONSTRUCTIONS

Unless otherwise specified, all of the reconstructed heights referred to in this report are based exclusively on the results of first-order levelings. All of the pre-1978 observed elevation differences attributed to the National Geodetic Survey have been drawn from the archival data of the National Geodetic Survey; none have been taken from the machine-readable data base for

California (National Geodetic Survey, 1978), since these data are known to have been contaminated owing to the use of improperly computed values for the rod excess (Mark and others, 1981, p. 2788-2790). The orthometric corrections required to convert the observed elevation differences into true height differences independent of survey path are in all cases based on observed or interpolated gravity values rather than theoretical or normal gravity. Nearly all of these orthometric corrections, moreover, are machine integrated results computed from the gravity values given in the machine-readable data base for California (National Geodetic Survey, 1978). Locally in southern California and throughout Arizona we have reverted to the use of a manual technique for the computation of the orthometric correction. This technique, which depends in turn on Bouguer gravity values, was developed by Petr Vaníček (Castle and others, 1984).

We have designated the survey route San Pedro-Los Angeles-Burbank-Saugus-Vincent (fig. 1) as the direct or primary route leading into 3219. All other routes into this mark are identified as alternative routes and have in common only that they bypass either of the two direct routes between Saugus and Vincent (fig. 1). The exclusion of this particular segment from any of the alternative routes is based on the assertion that the southern of these two routes in particular is especially susceptible to the accumulation of the explicitly path-dependent unequal-refraction error (Holdahl, 1982, p. 9374). Because we have been able to reconstruct only four sequential heights for 22Q, none of the routes leading into this mark has been designated as the direct or primary route, even though the two most recently determined heights are based on levelings over nearly coincident lines.

The tables comprising the bulk of this report are so organized that the reader can immediately identify the data source (by NGS line number, unless otherwise indicated), inclusive dates of leveling between marks, the junction bench marks used in the reconstruction, the observed elevation difference between junction bench marks, and the corresponding orthometric correction. Both the conventionally corrected observed elevation differences and the associated orthometric corrections are separately summed for each determination; the algebraic sum of these sums is the orthometric height for the indicated mark for the indicated period. Where the reconstruction of any of these heights has required the acceptance of certain assumptions or various unconventional corrections, this is explicitly indicated in the accompanying footnotes.

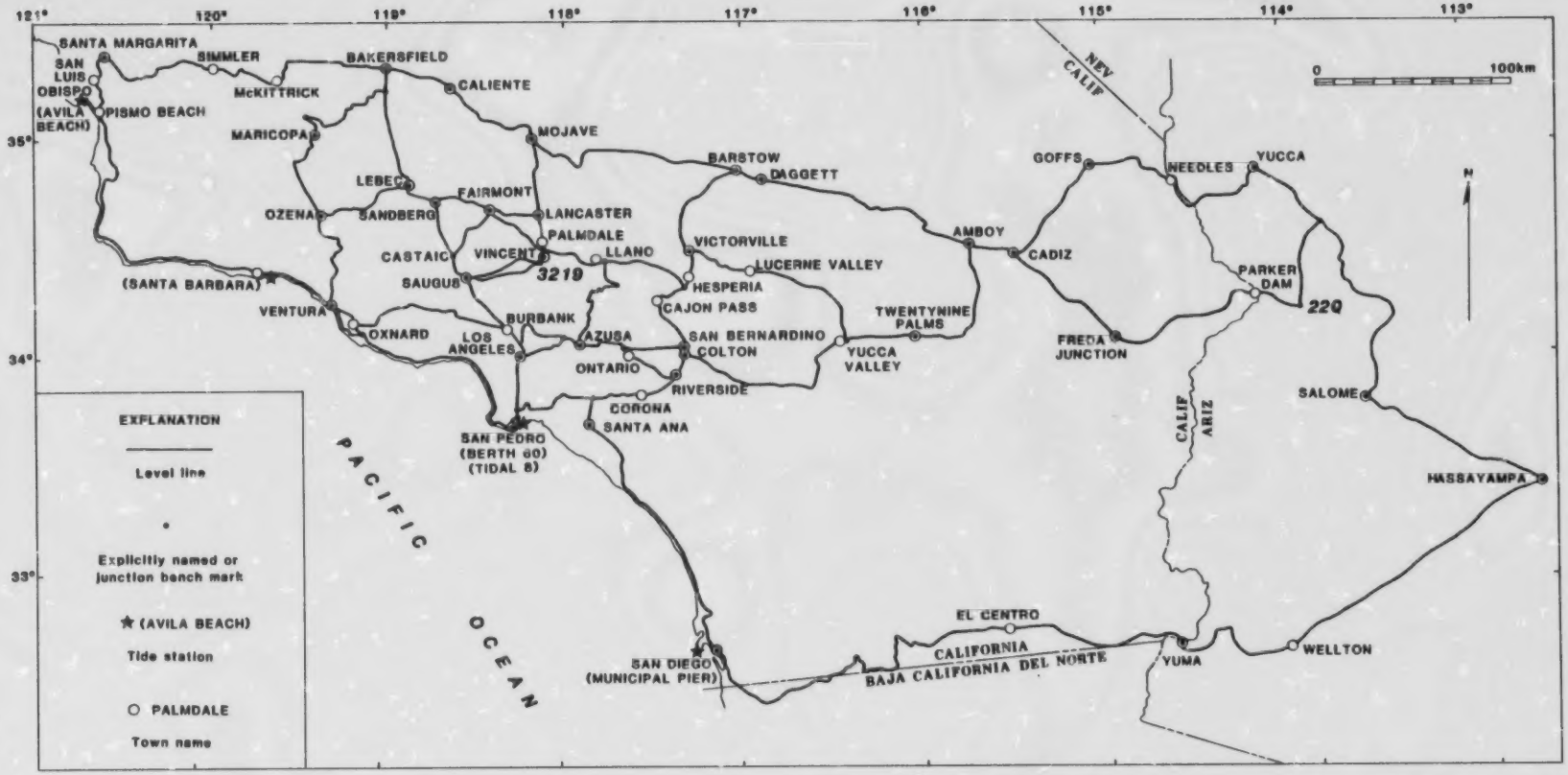

Figure 1. Map of southern California and southwestern Arizona showing routes of leveling used in geodetic reconstructions contained in this report.

TABLE 1. 3219 via direct route

1898

Route	Source	Dates of leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Pedro → Lang	USGS 19th Ann. Rept.[1/]	1897	T8 → 1690[2/]	+507.9779[3/]	+0.0365
Lang → Vincent	USGS summary book 9679[4/]	1902	1690 → 3219	+469.6384	+ .0389
			Sum + 3.3921 m =	+981.0084	+0.0754
			Orthometric height =	+981.0084	+0.0754
			=	981.0838	

Notes:

1/ Third-order.

2/ The height of the 1897 starting mark at San Pedro (BMA) with respect to the record height of Tidal 8 has been computed from comparisons of the heights of both BMA and Tidal 8 against the 1897 value for the MLLW tidal datum. The 1897 height of Tidal 8 with respect to MLLW is based on a 1933 measured value and the known rate of rise of sea level at the San Pedro tide station; that for BMA is based on a discontinuous series of late 19th century measurements.

An alternative reconstruction of the 1897 height of BMA with respect to Tidal 8 can also be based solely on geodetic ties in the San Pedro/Wilmington area. This reconstruction depends on 1920 and 1926 first-order leveling between bench marks Tidal 8 and 30LA, 1920 first-order leveling between 30LA and 7LA, and an 1897 third-order tie between 7LA and BMA. This reconstruction assumes invariance between the indicated bench marks during the interval 1897-1926 and results in an 1897 starting height for BMA that is only 0.0147 m lower than that derived from the independent sea-level-based measurements.

3/ This elevation difference is based on removal of an inferred 0.3048 m (even 1-ft.) blunder north of San Fernando.

4/ Second-order.

TABLE 2. 3219 via direct route

1902

Route	Source	Dates of leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Pedro → Pacoima	USGS 19th Ann. Rept.[1/]	1897	T8 → 1013	+301.8422[2/]	+0.0124
Pacoima → Vincent	USGS summary book 9679[3/]	1902	1013 → 3219	+675.7496	+ .0630
			Sum + 3.3921 m =	+980.9839	+0.0754
			Orthometric height =	+980.9839	+0.0754
			=	981.0593	

Notes:

1/ Third-order.

2/ See Table 1, Note 2 for an explanation of the establishment of an 1897 starting height for Tidal 8.

3/ Second-order.

TABLE 3. 3219 via Pacoima, Los Angeles Aqueduct, Mojave and Palmdale

1907

Route	Source	Dates of leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Pedro → Pacoima	USGS summary book 9349 [1]	5-7/1914	T8 → 1013	+305.5439 [2]	+0.0124
Pacoima → Mojave	L.A. Dept. of Water and Power	1-7/1907	1013 → 2732B	+524.2725	+ .0284 [3]
Mojave → Vincent	USGS summary book 9349 [1]	5-7/1914	2732B → 3219	+148.126	+ .0327
			Sum + 3.3921 m =	+981.3345 [4]	+0.0735
			Orthometric height =	+981.3345	+0.0735
			=	+981.4080	

Notes:

[1] Second-order.

[2] Based on an assumption of invariance between bench marks Tidal 8 and I33 from 1914-1926. The tie between these bench marks is based on the results of NGS line 82656 (1926).

[3] The orthometric correction for the segment between Pacoima and Mojave was manually computed.

[4] Based on an assumption of invariance between San Pedro and Pacoima and between Mojave and Vincent during the period 1907-1914. An alternative reconstruction, based on an assumption of invariance at Olancha (about 155 km north of Mojave) between 1905 and 1907, yields a value that is 0.035 m lower.

TABLE 4. 3219 via direct route

1914

Route	Source	Dates of leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Pedro → Vincent	USGS summary book 9349 [1/]	5-7/1914	T8 → 3219	+978.005 [2/]	+0.0754
			Sum + 3.3921 m =	+981.3971	+0.0754
			Orthometric height =	+981.3971	+0.0754
			=	981.4725	

Notes:

1/ Second-order.

2/ See Table 3, note 2.

TABLE 5. 3219 via direct route

1926

Route	Source	Dates of leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Pedro area	82656	5-6/1927	T8 → G52	+ 13.9917	0
San Pedro → Burbank	82583	8/1926	G52 → H36	+167.7270	+0.0009
Burbank → San Fernando	82466	8/1924	H36 → 1076	+142.9245	+ .0145
San Fernando → Saugus	82598	8-12/1926	1076 → 1171	+ 28.7116	+ .0012
Saugus → Lang	82600	9/1926	1171 → G53	+433.7592	+ .0199
Lang → Vincent	82598	8-12/1926	G53 → 3219	+190.6780	+ .0389
			Sum + 3.3921 m =	+981.1841	+0.0754
			Orthometric height =	+981.1841	+0.0754
			=	981.2595	

TABLE 6. 3219 via Saugus, Lebec, Bakersfield, Mojave and Palmdale

1926

Route	Source	Dates of leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Pedro area	82656	5-6/1927	T8 → G52	+ 13.9917	0
San Pedro → Burbank	82583	8/1926	G52 → H36	+167.7270	+0.0009
Burbank → San Fernando	82466	8/1924	H36 → 1076	+142.9245	+ .0145
San Fernando → Saugus → Bakersfield → Mojave → Palmdale → Vincent	82598	8-12/1926	1076 → 3219	+653.1749	+ .0718
			Sum + 3.3921 m =	+981.2102	+0.0872
			Orthometric height =	+981.2102	+0.0872
			=	981.2974	

TABLE 7. 3219 via Burbank, Oxnard, Santa Barbara, Santa Margarita, Bakersfield, Mojave and Palmdale

1927

Route	Source	Dates of leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Pedro → Burbank → Oxnard → Santa Barbara → Santa Margarita	74203	11/1919-3/20	T8 → C25	+280.4946	-0.0012 1/
Santa Margarita → Bakersfield	82727	10-12/1927	C25 → E55	-160.5531 2/	+ .0337
Bakersfield → Mojave → Vincent	82598	8-12/1926	E55 → 3219	+857.7412	+ .1373
			Sum + 3.3921 m =	+981.0748	+0.1698
			Orthometric height =	+981.0748	+0.1698
			=	981.2446	

Notes:

1/ The orthometric correction for the reach from San Pedro to Santa Margarita has been computed from the following sources:

San Pedro → Burbank	L-24301.6 (1978)	-0.0024 m
Burbank → Chatsworth	82642 (1927)	+ .0041
Chatsworth → Oxnard	L-9446 (1942)	- .0106
Oxnard → Santa Margarita	L-22292 (1970/71)	+ .0077

2/ Because the summary sheet for line 82727 provides orthometrically-corrected heights only based on normal or theoretical gravity, we have assumed that the normal orthometric correction computed for the 1927 leveling matches that computed for a 1957 survey (L-16345) that followed an identical route.

TABLE 8. 3219 via Saugus, Sandberg, Fairmont and Palmdale

1935

Route	Source	Dates of leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Pedro area	82656	5-6/1927	T8 → G52	+ 13.9917	0
San Pedro → Burbank	82583	8/1926	G52 → H36	+167.7270	+0.0009
Burbank → San Fernando	82466	8/1924	H36 → 1076	+142.9245	+ .0145
San Fernando → Sandberg	82598	8-12/1926	1076 → X53	+767.2784	+ .0769
Sandberg → Lancaster	L-5332 [1/]	3/1935	X53 → A57	-375.0870	- .0447
Lancaster → Vincent	82598	8-12/1926	A57 → 3219	+260.9496 [2/]	+ .0288
			Sum + 3.3921 =	+981.1763	+0.0764
			Orthometric height =	+981.1763	+0.0764
			=	981.2527	

Notes:

1/ Second-order.

2/ The elevation difference between Lancaster and Vincent has been corrected to allow for compaction-induced subsidence during the 1926-1935 junction interval at bench mark A57, Lancaster. An estimate of intrasurvey subsidence at Lancaster during the period 1926-1935 can be made by referring successive surveys to a local reference mark, specifically 2786 USGS, Fairmont, which lies well outside the actively subsiding area. A comparison of 1929 third-order and 1935 second-order levelings between Fairmont and Lancaster shows that bench mark A57 subsided 0.0229 m with respect to 2786 USGS during the interval 1929-1935 (USGS summary book B-3402 and NGS line L-5332). Thus in order to accommodate this subsidence, the 1926 elevation difference between Lancaster and Vincent obtained directly from NGS summary sheet 82598 has been increased by 0.0229 m. Any differential subsidence of bench mark A57 during the interval 1926-1929 is assumed to be negligible and is disregarded here.

TABLE 9. 3219 via Carpinteria, Ventura, Ozena, Lebec, Sandberg and Palmdale

1938

Route	Source	Dates of leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Pedro → Carpinteria	74203	11/1919-3/20	T8 → D29 [1/]	+ 8.8842	-0.0048 [2/]
Carpinteria → Ventura	L-8470	1/1939	D29 → I30 [1/]	- 7.0269	
Ventura → Wheeler Springs	L-1766	4-5/1934	I30 → K174	+1127.5221	+ .1088
Wheeler Springs → Ozena	L-4775	12/1934-2/35	K174 → 3450	- 80.1199	- .0764
Ozena → Lebec	L-9504.3 [3/]	2-3/1942	3450 → E54	+ 44.8391	+ .0220
Lebec → Sandberg	82598	8-12/1926	E54 → X53	- 2.2019	+ .0774
Sandberg → Lancaster	L-5332 [3/]	3/1935	X53 → A57	- 375.0870	- .0447
Lancaster → Vincent	32598	8-12/1926	A57 → 3219	+ 260.9496 [4/]	+ .0288
			Sum + 3.3921 m =	+ 981.1514	+ .1111
			Orthometric height =	+ 981.1514	+ .1111
			=	981.2625	

NOTES FOR TABLE 9

Notes:

1/ Castle and others (1984).

2/ The orthometric correction for the segment between San Pedro and Ventura has been computed from the following sources:

San Pedro → Burbank	L-24301.6 (1978)	-0.0024 m
Burbank → Chatsworth	82642 (1927)	+ .0041
Chatsworth → Oxnard	L-9446 (1942)	- .0106
Oxnard → Ventura	L-22292 (1970/71)	+ .0041

Orthometric corrections along the common route between Carpinteria and Ventura effectively cancel.

3/ Second-order.

4/ See Table 8, Note 2.

TABLE 10. 3219 via Saugus, Bakersfield, Mojave, Barstow, Amboy, Twentynine Palms, Yucca Valley, Victorville, Hesperia and Palmdale

1950

Route	Source	Dates of leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Pedro → Saugus	L-15577	3-5/1955	T8 → J52	+350.3882	+0.0143
Saugus → Bakersfield	L-14799	3-5/1953	J52 → S89	-224.3370	- .0773
Bakersfield → Mojave	L-14778	3-4/1953	S89 → Q49	+718.3339	+ .1014
Mojave → Daggett	L-18230	3-4/1961	Q49 → G293	-237.3754	- .0193
Daggett → Newberry Springs	L-11115	2-4/1944	G293 → P3	- 36.5524	+ .0014
Newberry Springs area	L-11062	1-2/1944	P3 → R3	- 24.4514	- .0022
Newberry Springs → Amboy	L-11115.A	2-4/1944	R3 → S702	-365.4009	- .0206
Amboy → Twentynine Palms	L-11067	2-3/1944	S702 → WWL17	+809.8888	+ .1095
Twentynine Palms → Yucca Valley	L-11065	1-2/1944	WWL17 → WWL2A	- 84.6112	- .0383
Yucca Valley → Lucerne Valley	L-11062	1-2/1944	WWL2A → V325	- 1.9828	+ .0019
Lucerne Valley → Victorville	L-3680.2	2/1935	V325 → R41	- 79.9357	- .0241
Victorville → Hesperia	L-15902	2-6/1956	R41 → F41	+186.3586	+ .0484
Hesperia → Palmdale	L-17772	2-3/1960	F41 → D430	-141.1845	- .0776
Palmdale → Vincent	L-15618	5-6/1955	D430 → 3219	+108.6817	+ .0151
			Sum + 3.3921 m =	+981.2120	+0.0326
			Orthometric height =	+981.2120	+0.0326
			=	981.2446	

TABLE 11. 3219 via direct route

1955

Route	Source	Dates of leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Pedro → Saugus	L-15577	3-5/1955	T8 → 1171	+353.1663	+0.0144
Saugus → Vincent	L-15618	5-6/1955	1171 → 3219	+624.6146	+ .0600
			Sum + 3.3921 m =	+981.1730	+0.0744
			Orthometric height =	+981.1730	+0.0744
			=	981.2474	

TABLE 12. 3219 via Saugus, Lebec, Bakersfield, Mojave and Palmdale

1955

Route	Source	Dates of leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Pedro → Saugus	L-15577	3-5/1955	T8 → 1171	+353.1663	+0.0144
Saugus → Bakersfield	L-14799	3-5/1953	1171 → S89	-227.1414	- .0771
Bakersfield → Mojave	L-14778	3-4/1953	S89 → Q49	+718.3339	+ .1025
Mojave → Vincent	L-15618	5-6/1955	Q49 → 3219	+133.4465	+ .0327
			Sum + 3.3921 =	+981.1974	+0.0725
			Orthometric height =	+981.1974	+0.0725
			=	981.2699	

TABLE 13. 3219 via 22Q, Freda Junction, Barstow, Mojave and Palmdale

1955

Route	Source	Dates of leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Pedro → 22Q	Table 41, this report	1975/78	T8 → 22Q	+183.1580[1/]	+0.0041
22Q → Cadiz	L-7407	1931	22Q → 10A	+ 41.3663	- .0050
Cadiz → Daggett	L-11115.A	2-4/1944	10A → G293	+382.4137	+ .0194
Daggett → Mojave	L-18230	3-4/1961	G293 → Q49	+237.3754	+ .0231
Mojave → 3219	L-15618	5-6/1955	Q49 → 3219	+133.4465	+ .0327
			Sum + 3.3921 m =	+981.1520	+0.0743
			Orthometric height =	+981.1520	+0.0743
			=	981.2263	

Notes:

1/ This elevation difference has been corrected to a 1955 equivalent by assuming invariance between 22Q and the San Diego tidal bench marks and allowing for the known rate of uplift (1.56 mm/yr) of the San Pedro tide station with respect to San Diego (which is assumed to be fixed with respect to a tectonically invariant datum such as the reference ellipsoid) during the period 1955-1978 (Castle and Elliott, 1982).

2/ Because the line extending eastward from Mojave to at least Freda Junction almost certainly remained free of regional deformation during the period 1931.0-1961.3 (Castle and others, 1984, p. 71-79, 84-85), the indicated observed elevation difference is assumed to match that which would have been obtained had this leveling been carried out in 1955.

TABLE 14. 3219 via Ventura, Santa Barbara, Santa Margarita, McKittrick, Bakersfield, Mojave, Barstow, Barstow, Hesperia and Palmdale

1957

Route	Source	Dates of leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Pedro → Santa Margarita	74203	11/1919–3/20	T8 → E25	+304.7565	-0.0064 [2/]
Santa Margarita → McKittrick	L-16345	4/1956–8/57	E25 → L2100	+ 4.8519 [1/]	+ .0423
McKittrick → Bakersfield	L-16280	6-7/1957	L2100 → F55	-189.8426	- .0112
Bakersfield area	L-14799	3-5/1953	F55 → S89	+ 6.1816	+ .0003
Bakersfield → Mojave	L-14778	3-4/1953	S89 → Q49	+718.3339	+ .1026
Mojave → Barstow	L-18230	3-4/1961	Q49 → E43	-204.1004	- .0228
Barstow → Hesperia	L-15902	2-6/1956	E43 → E41	+395.0282	+ .1085
Hesperia → Palmdale	L-17772	2-3/1960	E41 → D430	-166.1639	- .0776
Palmdale → Vincent	L-15618	5-6/1955	D430 → 3219	+108.6817	+ .0151
			Sum + 3.3921 m =	+981.1190	+0.1508
			Orthometric height =	+981.1190	+0.1508
			=	981.2698	

NOTES FOR TABLE 14

Notes:

1/ Based on an assumption of invariance at the Santa Margarita junction mark during the interval 1919/1920–1956/1957.

2/ The orthometric correction for the segment between San Pedro and Santa Margarita was computed from the following sources:

San Pedro → Ventura	L-21729, L-21537, L-21366 (1968)	-0.0048 m
Ventura → Gaviota	L-17847 (1960)	- .0010
Gaviota → Surf	L-17778 (1960)	- .0011
Surf → Santa Margarita	L-15972 (1956)	+ .0005

TABLE 15. 3219 via Avila Beach, Santa Margarita
1957 McKittrick, Bakersfield, Mojave, Barstow,
Hesperia and Palmdale

Route	Source	Dates of leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
Avila Beach[1/] → Santa Margarita	L-16345	4/1956-8/57	Tidal 12 → E25	+304.3046	+0.0125
Santa Margarita → McKittrick	L-16345	4/1956-8/57	E25 → L2100	+ 4.8519	+ .0423
McKittrick → Bakersfield	L-16280	6-7/1957	L2100 → F55	-189.8426	- .0112
Bakersfield area	L-14799	3-5/1953	F55 → S89	+ 6.1816	+ .0003
Bakersfield → Mojave	L-14778	3-4/1953	S89 → Q49	+718.3339	+ .1026
Mojave → Barstow	L-18230	3-4/1961	Q49 → E43	-204.1004	- .0228
Barstow → Hesperia	L-15902	2-6/1956	E43 → E41	+395.0282	+ .1085
Hesperia → Palmdale	L-17772	2-3/1960	E41 → D430	-166.1639	- .0776
Palmdale → Vincent	L-15618	5-6/1955	D430 → 3219	+108.6817	+ .0151
			Sum + 3.7579 m =	+981.0329	+0.1697
			Orthometric height =	+981.0329	+0.1697
			=	981.2026	

NOTES FOR TABLE 15

Notes:

1/ Based on a tie between local mean sea-level values at the San Pedro and Avila Beach tide stations. The heights for the starting marks with respect to LMSL at both San Pedro and Avila Beach have been computed from 19 years of annual sea-level means centering on 1957 and result in values of 3.3711 m and 3.7369 m, for bench marks Tidal 8 and Tidal 12, respectively. Based on an assumption of zero sea-surface topography between the San Pedro and Avila Beach tide stations, these values can be referred to the record 3.3921-m starting height of Tidal 8 at San Pedro by adding 0.0210 m to both of the 1957 heights with respect to local mean sea level. The starting height for bench mark Tidal 12 at Avila Beach is computed as 3.7579 m.

TABLE 16. 3219 via Saugus, Lebec, Bakersfield, Lebec, Castaic, Fairmont and Palmdale

1959

Route	Source	Dates of leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Pedro → Saugus	L-15577	3-5/1955	T8 → 1171	+ 353.1663	+0.0143
Saugus → Bakersfield	L-14799	3-5/1953	1171 → C55	- 232.4770	- .0773
Bakersfield → Lebec	L-17212	4/1959	C55 → BM2	+1042.4668 1/	+ .1216
Lebec → Castaic	L-14799	3-5/1953	BM2 → X370	- 791.6129	- .0485
Castaic → Fairmont	Calif. Dept. of Water Resources 2/	2-3/1961	X370 → H1044	+ 473.1889	+ .0405
Fairmont → Palmdale	L-17772	2-3/1960	H1044 → G57	+ 24.4506	+ .0181
Palmdale → Vincent	L-15618	5-6/1955	G57 → 3219	+ 108.6817	+ .0091
			Sum + 3.3921 m =	+ 981.2565	+0.0778
			Orthometric height =	+ 981.2565	+0.0778
			=	+ 981.3343	

Notes

1/ Based on an assumption of invariance of bench mark C55, Bakersfield, during the interval 1953/1955-1959.

2/ Second-order.

TABLE 17. 3219 via Saugus, Bakersfield, Maricopa, Ozena, Lebec, Castaic, Fairmont and Palmdale

1959

Route	Source	Dates of leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Pedro → Saugus	L-15577	3-5/1955	T8 → 1171	+353.1663	+0.0143
Saugus → Bakersfield	L-14799	3-5/1953	1171 → C55	-232.4770	- .0773
Bakersfield → Greenfield	L-17212	4/1959	C55 → V54	- 29.1810 [1]	+ .0054
Greenfield area	L-17209.6 [2]	4/1959	V54 → L542	+ 49.7325	+ .0032
Greenfield → Taft	L-17209.8 [2]	4/1959	L542 → Z537	+127.3091	+ .0005
Taft → Maricopa	L-17200.2	4/1959	Z537 → C445	+338.0460	+ .0202
Maricopa area	L-17398	1-4/1959	C445 → G306	+143.8080	+ .0306
Maricopa → Ozena	L-17200.1	4/1959	C438 → TBM3	+327.1455	+ .0671
Ozena → Frazier Park	L-17206.5	4/1959	TBM3 → J605	+488.9013	+ .0512
Frazier Park → Lebec	L-17206.3	4-5/1959	J605 → BM2	-403.2853	- .0814
Lebec → Castaic	L-14799	3-5/1953	BM2 → X370	-791.6129	- .0485
Castaic → Fairmont	Calif. Dept. of Water Resources [2]	2-3/1961	X370 → N1044	+473.1889	+ .0405
Fairmont → Palmdale	L-17772	2-3/1960	N1044 → G57	+ 24.4506	+ .0181
Palmdale → Vincent	L-15618	5-6/1955	G57 → 3219	+108.6817	+ .0091
			Sum + 3.3921 m =	+981.2658	+0.0530
			Orthometric height =	+981.2658	+0.0530
			=	981.3188	

NOTES FOR TABLE 17

Notes:

1/ Based on an assumption of invariance of bench mark C55, Bakersfield, during the period 1953/1955-1959.

2/ Second-order.

TABLE 18. 3219 via direct route

1961

Route	Source	Dates of leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Pedro → Los Angeles	L-18364	4/1961	T8 → L1141	+ 86.3974	-0.0011
Los Angeles → Burbank	L-18296	3-5/1961	L1141 → H43	+ 90.4252	+ .0004
Burbank → Saugus → Vincent	L-18299	3-5/1961	H43 → 3219	+801.0188	+ .0754
			Sum + 3.3921 m =	+981.2335	+0.0747
			Orthometric height =	+981.2335	+0.0747
			=	981.3082	

TABLE 19. 3219 via Los Angeles, Azusa, San Gabriel Mountains, Llano and Palmdale

1961

Route	Source	Dates of leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Pedro → Los Angeles	L-18364	4/1961	T8 → L1141	+ 86.3974	-0.0011
Los Angeles → Azusa	L-18296	3-5/1961	L1141 → 11-26A	+ 68.2962	+ .0032
Azusa → Falling Springs	L-18535	10/1961	11-26A → R116	+903.5135	+ .0877
Falling Springs → Llano	L-18697	5-6/1962	R116 → 3409	- 22.5668	- .0009
Llano → Palmdale	L-17772	2-3/1960	3409 → K811	-176.4475	- .0434
Palmdale → Vincent	L-18299	3-5/1961	K811 → 3219	+118.8204	+ .0136
			Sum + 3.3921 m =	+981.4053	+0.0591
			Orthometric height =	+981.4053	+0.0591
			=	981.4644	

TABLE 20. via Los Angeles, Azusa, Colton, Cajon Pass,
1961 Barstow, Mojave and Palmdale

Route	Source	Dates of leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Pedro → Los Angeles	L-18364	4/1961	T8 → L1141	+ 86.3974	-0.0011
Los Angeles → Azusa → Colton	L-18296	3-5/1961	L1141 → N516	+228.8755	+ .0182
Colton area	L-18544	9-11/1961	N516 → X472	- 23.1146	- .0018
Colton → Barstow	L-18547	10-11/1961	X472 → E43	+348.2388	- .0266
Barstow → Mojave	L-18230	3-4/1961	E43 → S368	+188.8682	+ .0246
Mojave → Palmdale → Vincent	L-18299	3-5/1961	S368 → 3219	+148.7415	+ .0312
			Sum + 3.3921 m =	+981.3989	+0.0445
			Orthometric height =	+981.3989	+0.0445
			=	981.4434	

TABLE 21. 3219 via direct route

1961/62

Route	Source	Dates of leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Pedro → Los Angeles	L-18364	4/1961	T8 → L1141	+ 86.3974	-0.0011
Los Angeles → Burbank	L-18296	3-5/1961	L1141 → H43	+ 90.4252	+ .0004
Burbank → Saugus	L-18299	3-5/1961	H43 → X898	+171.9204	+ .0147
Saugus → Vincent	L.A. Co. Dept. of Co. Engineer	12/1961-3/62	X898 → 3219	+629.2762 1/	+ .0636
			Sum + 3.3921 m =	+981.4113	+0.0776
			Orthometric height =	+981.4113	+0.0776
			=	981.4889	

Notes:

1/ This elevation difference is based on uncorrected field elevations.

TABLE 22. 3219 via direct route

1964

Route	Source	Dates of leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Pedro → Saugus	L-19752	3-6/1964	T8 → 1171	+353.1689	+0.0148
Saugus → Vincent	L-19781	4-5/1964	1171 → 3219	+624.8522	+ .0600
			Sum + 3.3921 m =	+981.4132	+0.0748
			Orthometric height =	+981.4132	+0.0748
			=	981.4880	

TABLE 23. 3219 via Saugus, Sandberg, Fairmont and Palmdale

1964

Route	Source	Dates of leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Pedro → Gorman	L-19752	3-6/1964	T8 → C370	+1016.3739	+0.0758
Gorman → Sandberg	L-19775	7-8/1964	C370 → 102-72	- 67.6689	- .0033
Sandberg → Palmdale	L-19787	8-9/1964	102-72 → H1045	- 57.4380	- .0217
Palmdale area	L-19778.7	7/1964	H1045 → P429	- 32.9891	+ .0056
Palmdale → Vincent	L-19781	4-5/1964	P429 → 3219	+ 119.7405	+ .0166
			Sum + 3.3921 m =	+ 981.4105	+0.0730
			Orthometric height =	+ 981.4105	+0.0730
			=	981.4835	

TABLE 24. 3219 via direct route

1965

Route	Source	Dates of leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Pedro → Los Angeles	L-19752	3-6/1964	T8 → L1141	+ 86.3850	-0.0011
Los Angeles → Saugus	L-20169	1-4/1965	L1141 → J52	+264.0561	+ .0154
Saugus → Lang	L-20145	3/1965	J52 → M486	+160.1121	- .0030
Lang → Vincent	L-20298	4-6/1965	M486 → 3219	+467.4628	+ .0635
			Sum + 3.3921 m =	+981.4081	+0.0748
			Orthometric height =	+981.4081	+0.0748
			=	981.4829	

TABLE 25. 3219 via direct route

1968

Route	Source	Dates of leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Pedro area	L-21729	8-9/1968	T8 → 21-03690	+ 9.7367	+0.0001
San Pedro → Los Angeles	L-21731	2/1968-1/69	21-03690 → 338	+ 90.2727	+ .0002
Los Angeles → San Fernando	L-21739	5/1968	338 → 04-00872	+293.0541	+ .0165
San Fernando → Saugus	L-21723	5-6/1968	04-00872 → 1171	- 39.8731	- .0018
Saugus → Vincent	L-21589	1-8/1968	1171 → 3219	+624.8145	+ .0628
			Sum + 3.3921 m =	+981.3970	+0.0778
			Orthometric height =	+981.3970	+0.0778
			=	981.4748	

TABLE 26. 3219 via Ventura, Ojai, Ozena, Lebec, Lancaster and Palmdale

1968

Route	Source	Dates of leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Pedro area	L-21729	8-9/1968	T8 → 21-03690	+ 9.7367	+0.0001
San Pedro → Oxnard	L-21537	4-7/1968	21-03690 → U1051	+ 9.8440	- .0006
Oxnard → Ventura → Ojai → Ozena → Lebec	L-21366	2-4/1968	U1051 → B605	+1118.2573	+ .0609
Lebec → Sandberg	L-21589	1-8/1968	B605 → 102-81	- 127.7462	+ .0125
Sandberg → Lancaster	L-21681	11/1968-1/69	102-81 → M487	- 309.8335	- .0416
Lancaster → Palmdale	L-21782	11-12/1968	M487 → LOFT	+ 202.8153	+ .0292
Palmdale → Vincent	L-21589	1-8/1968	LOFT → 3219	+ 75.0335	+ .0102
			Sum + 3.3921 m =	+ 981.4992	+0.0707
			Orthometric height =	+ 981.4992	+0.0707
			=	981.5699	

TABLE 27. 3219 via Orange, Riverside, Cajon Junction, Llano and Palmdale
1968

Route	Source	Dates of leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Pedro area	L-21729	8-9/1968	T8 → 21-03690	+ 9.7367	+0.0001
San Pedro → Seal Beach	L-21537	4-7/1968	21-03690 → CC6	- 1.6368	+ .0002
Seal Beach → Orange	L-21596.1	5/1968-6/69	CC6 → S778	+ 15.9321	+ .0001
Orange → Orange Co. line	L-21807	6/1968-4/69	S778 → 2C77	+ 46.3217	+ .0004
Orange Co. line → Corona	L-21868	8/1968-6/69	2C77 → 2J21	+ 58.1587	+ .0008
Corona → Riverside	L-21764	12/1968-10/69	2J21 → R449	+152.5781	+ .0078
Riverside → Cajon Junction	L-21485	1-12/1968	R449 → Summit	+881.8565	+ .0980
Cajon Junction → Llano	L-21488	6-7/1968	Summit → N1046	-132.7094	- .0353
Llano → Vincent	L-21589	1-8/1968	N1046 → 3219	- 52.1984	- .0415
			Sum + 3.3921 m =	+981.4313	+0.0306
			Orthometric height =	+981.4313	+0.0306
			=	981.4619	

TABLE 28. 3219 via Orange, Colton, White Water, Yucca Valley, Victorville, Cajon Junction, Llano and Palmdale

1968

Route	Source	Dates of leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Pedro area	L-21729	8-9/1968	T8 → 21-03690	+ 9.7367	+0.0001
San Pedro → Seal Beach	L-21537	4-7/1968	21-03690 → CC6	- 1.6368	+ .0002
Seal Beach → Orange	L-21596.1	5/1968-6/69	CC6 → S778	+ 15.9321	+ .0001
Orange → Orange Co. line	L-21807	6/1968-4/69	S778 → 2C77	+ 46.3217	+ .0004
Orange Co. line → Corona	L-21868	8/1968-6/69	2C77 → 2J21	+ 58.1587	+ .0008
Corona → Riverside	L-21764	12/1968-10/69	2J21 → R449	+152.5781	+ .0078
Riverside → Colton	L-21485	1-12/1968	R449 → D39	+ 12.6984	+ .0018
Colton → Riverside Co. line	L-21618	9-10/1968	D39 → 706-5	+156.7366	+ .0152
Riverside Co. line → White Water	L-21770	1/1968-6/69	706-5 → 603-70	- 6.7787	+ .0093
White Water → Yucca Valley	L-21776	3-4/1969	603-70 → M721	+341.6661	+ .0259
Yucca Valley → Victorville	L-21975	1-12/1969	M721 → B1159	+ 42.0813	- .0552
Victorville → Cajon Junction	L-21485	1-12/1968	B1159 → Summit	+335.4983	+ .0523
Cajon Junction → Llano	L-21488	6-7/1968	Summit → N1046	-132.7094	- .0353
Llano → Vincent	L-21589	1-8/1968	N1046 → 3219	- 52.1984	- .0415
			Sum + 3.3921 m =	+981.4768	-0.0181
			Orthometric height =	+981.4768	-0.0181
			=	981.4587	

TABLE 29. 3219 via direct route

1971

Route	Source	Dates of leveling	Bench mark end points	Observed elevation difference (m)	Orthometric correction (m)
San Pedro → Newhall	L-22429.1	2-7/1971	T8 → 60-32C	+410.8400	+0.0168
Newhall → Saugus	L-22427.1	3-4/1971	60-32C → 60-38	- 30.5508	- .0025
Saugus area	L-22427.1	3-4/1971	60-38 → H486	+ 91.3755	
Saugus → Vincent	L-22422	4-6/1971	H486 → 3219	+506.4095	+ .0605
			Sum + 3.3921 m =	+981.4663	+0.0748
			Orthometric height =	+981.4663	+0.0748
			=	981.5411	

TABLE 30. 3219 via Los Angeles, Azusa, San Gabriel Mountains, Llano and Palmdale

1971

Route	Source	Dates of leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Pedro → Los Angeles	L-22429.1	2-7/1971	T8 → 28-30	+ 47.1211	+0.0011
Los Angeles → San Gabriel	L-22427.2	6/1970-5/71	28-30 → 31-24	+ 34.7350	- .0016
San Gabriel → Azusa	L-22613	11/1970-10/71	31-24 → 11-26A	+ 72.8723	+ .0023
Azusa → Llano	L-22515	6-10/1971	11-26A → S1220	+904.4439	+ .0832
Llano → California Aqueduct	L-22498.2	8-9/1971	S1220 → 106-28	-127.9427	- .0353
Calif. Aqueduct → Palmdale	L-22498.1	8-10/1971	106-28 → D430	- 61.7839	- .0208
Palmdale → Vincent	L-22422	4-6/1971	D430 → 3219	+108.6953	+ .0151
			Sum + 3.3921 m =	+981.5331	+0.0440
			Orthometric height =	+981.5331	+0.0440
			=	981.5771	

TABLE 31. 3219 via direct route

1974

Route	Source	Dates of leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Pedro area	L-23644	1-2/1974	T8 → 21-03690	+ 9.7053	+0.0001
San Pedro → Los Angeles	L-23611	1-3/1974	21-03690 → 338	+ 90.3218	- .0001
Los Angeles → San Fernando	L-23614	7-11/1973	338 → 04-00855	+276.0888	+ .0162
San Fernando → Saugus	L-23691	3-7/1973	04-00855 → 1171	- 22.8927	- .0013
Saugus → Vincent	L-23679	11/1972-3/73	1171 → 3219	+624.9067	+ .0628
			Sum + 3.3921 m =	+981.5220	+0.0777
			Orthometric height =	+981.5220	+0.0777
			=	981.5997	

TABLE 32. 3219 via Saugus, Lebec, Bakersfield, Mojave, and Palmdale

1974

Route	Source	Dates of leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Pedro area	L-23644	1-2/1974	T8 → 21-03690	+ 9.7053	+0.0001
San Pedro → Los Angeles	L-23611	1-3/1974	21-03690 → 338	+ 90.3218	- .0001
Los Angeles → San Fernando	L-23614	7-11/1973	338 → 04-00855	+276.0888	+ .0162
San Fernando → Saugus	L-23691	3-7/1973	04-00855 → 1171	- 22.8927	- .0013
Saugus → Castaic Junction	L-23677	3-4/1973	1171 → U370	- 47.4851	- .0023
Castaic Junction → Gorman	L-23675	3-7/1973	U370 → 102-79	+720.5658	+ .0622
Gorman → Grapevine	L-23673	5-7/1974	102-79 → H537	-260.3644	- .0876
Grapevine → Bakersfield	L-22757	3-4/1972	H537 → TBM IT	-641.3790	- .0448
Bakersfield → Caliente	L-22754	3-4/1972	TBM IT → L537	+166.8267	+ .0166
Caliente → Mojave → Rosamond	L-23208	11/1973-2/74	L537 → E1147	+443.0612	+ .0860
Rosamond → Los Angeles Co. line	L-23685	2-10/1974	E1147 → M487	- 34.2195	- .0050
Los Angeles Co. line → Palmdale	L-23671	10/1973-2/74	M487 → LOFT	+203.5111	+ .0292
Palmdale → Vincent	L-23679	11/1972-3/73	LOFT → 3219	+ 74.4008	+ .0104
			Sum + 3.3921 m =	+981.5329	+0.0796
			Orthometric height =	+981.5329	+0.0796
			=	981.6125	

TABLE 33. 3219 via Orange, Riverside, Cajon Junction, Llano and Palmdale

1974

Route	Source	Dates of leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Pedro area	L-23644	1-2/1974	T8 → 21-03690	+ 9.7053	+0.0001
San Pedro → Seal Beach	L-23699	9-10/1973	21-03690 → CC6	- 1.6226	- .0004
Seal Beach → Buena Park	L-23443	1-6/1974	CC6 → S778	+ 15.9543	- .0001
Buena Park → Atwood	L-23434	4-6/1974	S778 → 2C77	+ 46.3261	+ .0005
Atwood → Corona	L-23437	2-8/1974	2C77 → 2J21	+ 58.1613	+ .0008
Corona → Riverside	L-23919	9-11/1974	2J21 → R449	+152.6001	+ .0046
Riverside → Cajon Junction	L-23224.B	8/1973-1/74	R449 → 704-01	+888.7630	+ .1043
Cajon Junction → Llano	L-23224.C	7-8/1973	704-01 → M1046	-141.0198	- .0354
Llano → Palmdale	L-23681	7-8/1973	M1046 → LOFT	-125.1638	- .0541
Palmdale → Vincent	L-23679	11/1972-3/73	LOFT → 3219	+ 74.4008	+ .0104
			Sum + 3.3921 m =	+981.4968	+0.0307
			Orthometric height =	+981.4968	+0.0307
			=	981.5275	

TABLE 34. 3219 via direct route

1976

Route	Source	Dates of leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Pedro → La Cañada	L-24116	8-9/1976	T8 → 09-00509	+453.2743	+0.0149
La Cañada → Vincent	L.A. County	7/1976	09-00509 → 3219	+524.6892	+ .0680
			Sum + 3.3921 m =	+981.3556	+0.0829
			Orthometric height =	+981.3556	+0.0829
			=	981.4385	

TABLE 35. 3219 via direct route

1978

Route	Source	Dates of leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Pedro area	L-24301.1	1-5/1978	T8 → 21-03269	+ 8.8482	+0.0002
San Pedro → Burbank → Saugus → Vincent	L-24301.6	1-4/1978	21-03269 → 3219	+969.0790	+0.0750
			Sum + 3.3921 m =	+981.3193	+0.0752
			Orthometric height =	+981.3193	+0.0752
			=	981.3945	

TABLE 36. 3219 via Saugus, Lebec, Bakersfield, Mojave, and Palmdale
1978

Route	Source	Dates of leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Pedro area	L-24301.1	1-5/1978	T8 → 21-03269	+ 8.8482	+0.0002
San Pedro → Saugus	L-24301.6	1-4/1978	21-03269 → J52	+341.5043	+ .0132
Saugus → Castaic Junction	L-24301.9	1-4/1978	J52 → U370	- 44.7732	- .0020
Castaic Junction → Lebec	L-24301.8	1-4/1978	U370 → BM2	+857.6125	+ .0486
Lebec → Bakersfield → Mojave	L-24301.5	1-4/1978	BM2 → Q49	-318.8227	- .0195
Mojave → Palmdale → Vincent	L-24301.6	1-4/1978	Q49 → 3219	+133.4894	+ .0327
			Sum + 3.3921 m =	+981.2506	+0.0732
			Orthometric height =	+981.2506	+0.0732
			=	981.3238	

TABLE 37. 3219 via Los Angeles, Azusa, San Gabriel Mountains, Llano and Palmdale

1978

Route	Source	Dates of leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Pedro area	L-24301.1	1-5/1978	T8 → 21-03269	+ 8.8482	+0.0002
San Pedro → Burbank	L-24301.6	1-4/1978	21-03269 → V768	+114.5526	- .0026
Burbank → Azusa	L-24301.13	1-4/1978	V768 → 11-26A	+ 31.2192	+ .0113
Azusa → Llano	L-24301.15	1-5/1978	11-26A → Largo Vista RM1	+881.0557	+ .0787
Llano → Palmdale	L-24301.14	2-4/1978	Largo Vista RM1 → Q1147	-115.9859	- .0378
Palmdale → Vincent	L-24301.6	1-4/1978	Q1147 → 3219	+ 58.2760	- .0005
			Sum + 3.3921 m =	+981.3579	+0.0493
			Orthometric height =	+981.3579	+0.0493
			=	981.4072	

TABLE 38. 22Q via San Diego, Colton, Barstow, Goffs and Yucca

1906

Route	Source	Dates of leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Pedro → San Diego	L-386, L-570	1931/1932/1933	T8 → Tidal 4	+0.2980 [1/]	+0.0020
San Diego → Barstow	USC GS Spec. Pub. 18	1906	Tidal 4 → H3	+636.8531	- .0635
Barstow → Goffs	P-60540	12/1906-5/07	H3 → L5	+146.0384	+ .0722
Goffs → Yucca	P-63613.A	4-9/1909	L5 → P	-235.9400	- .0352
Yucca → Yucca Junction	82625	1927	P → L-11	+377.1889	+ .0385
Yucca Junction → 22Q	L-7407	1931	L-11 → 22Q	-741.1874	- .0398
			Sum + 3.3921 m =	+186.6431	-0.0258
			Orthometric height =	+186.6431	-0.0258
			=	186.6173	

NOTES FOR TABLE 38.

Notes:

1/

The 1931/1932/1933 elevation difference between San Pedro and San Diego has been corrected to a 1906 equivalent by allowing for movements known to have occurred along this line both between 1907 and 1931/1932/1933 and during the course of the 1931/1932/1933 leveling. Specifically, a correction has been applied to the 1932/1933 starting height of the junction bench mark at Santa Ana in order to provide for about 0.01 m of compaction-induced subsidence that occurred at this mark during the 1931/1932-1932/1933 junction interval (Castle and Elliott, 1982, p. 7005). Secondly, relative movements between the San Pedro and San Diego tide stations have been assessed by comparing linear regressions through the 19-yr mean sea level curves at both tide stations. Linear regressions through the pre-1934 San Diego mean sea-level curve (when the primary San Diego tide station was located at the Quarantine Station near Point Loma) and through the entire series at San Pedro indicate that sea level at the Quarantine Station (abandoned in 1927) has been rising at about 2.98 ± 0.11 mm/yr with respect to San Pedro (Castle and Elliott, 1982, p. 7010, 7016). Interpretation of this rise in sea level as relative subsidence at the Quarantine Station indicates that the 1906 starting height for bench mark Tidal 4 at San Diego (with respect to Tidal 8) was approximately 0.0775 m above that which obtained in 1932/33.

San Pedro (Tidal 8) → Santa Ana (R98) (via A33, Florence, and T33, Buena Park) (L-386)	+41.3169 m
Compaction-induced subsidence at Santa Ana during the 1931/1932-1932/1933 junction interval.	- 0.01
Santa Ana (R98) → San Diego (Tidal 4) (L-570)	-41.0864
Subsidence of Tidal 4, San Diego, with respect to Tidal 8, San Pedro, between 1906 and 1932/1933. (This correction is positive because the 1906 elevation of Tidal 4 was 0.0775 m higher than that which obtained in 1932/1933.)	+ 0.0775
	+ 0.2980

TABLE 39. 22Q via San Diego, Yuma, Hassayampa, and Yucca

1927

Route	Source	Dates of leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Pedro → San Diego	L-386, L-570	1931/1932/1933	T8 → Tidal 4	+2.3688[1/]	+0.0022
San Diego → Yuma	82606	12/1926-3/27	M57 → V7	+ 35.7325	+ .0172
Yuma → Hassayampa	82632	1927	V7 → 010	+232.9231	+ .0039
Hassayampa → Yucca	82625	1927	010 → L11	+653.3387	- .0029
Yucca → 22Q	L-7407	1931	L11 → 22Q	-741.1874	- .0398
			Sum + 3.3921 m =	+186.5678	-0.0194
			Orthometric height =	+186.5678	-0.0194
			=	186.5484	

NOTES FOR TABLE 39.

Notes:

1/ The 1931/1932/1933 elevation difference between San Pedro and San Diego has been corrected to a 1927 equivalent by allowing for movements known to have occurred along this line both between 1927 and 1931/1932/1933 and during the course of the 1931/1932/1933 leveling. Specifically, a correction has been applied to the 1932/1933 starting height of the junction bench mark at Santa Ana in order to provide for about 0.01 m of compaction-induced subsidence that occurred at this mark during the 1931/1932-1932/1933 junction interval (Castle and Elliott, 1982, p. 7005). Secondly, relative movements between the San Pedro and San Diego tide stations have been assessed by comparing linear regressions through the 19-yr mean sea level curves at both tide stations. Linear regressions through the post-1934 San Diego tide station records (when the primary San Diego tide station was located at the Municipal Pier along central San Diego Bay) and through the entire series at San Pedro indicate that sea level at the Municipal Pier has been rising at only about 1.56 ± 0.07 mm/yr with respect to San Pedro (Castle and Elliott, 1982, p. 7010, 7016). Interpretation of this rise in sea level as relative subsidence at the Municipal Pier indicates that the 1927 starting height for bench mark M57 at San Diego (with respect to Tidal 8) was approximately 0.0094 m above its 1932/1933 height.

San Pedro (Tidal 8) → Santa Ana (R98) (via A33, Florence, and T33, Buena Park) (L-386)	+41.3169 m
Compaction-induced subsidence at Santa Ana during the 1931/1932-1932/33 junction interval	- 0.01
Santa Ana (R98) → San Diego (Tidal 4) (L-570)	-38.9475
Subsidence of Tidal 4, San Diego, with respect to Tidal 8, San Pedro, between 1927 and 1932/1933. (This correction is positive because the 1927 elevation of M 57 was 0.0094 m higher than that which obtained in 1932/1933.)	+ 0.0094
	+ 2.3688

TABLE 40. 22Q via Los Angeles, Saugus, Palmdale, Mojave, Barstow, Amboy and Freda Junction

1938

Route	Source	Dates of leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Pedro → Barstow	82466, 82583, 82598, 82600, L-1; L-18364, L-18299, L-18296	1938	T8 → E43	+640.2429 [1/]	+0.0170
Barstow → Daggett	L-18230	3-4/1961	E43 → G293	- 33.2750	- .0001
Daggett → Cadiz	L-11115.A	2-4/1944	G293 → 10A	-382.4137	- .0194
Cadiz → 22Q	L-7407	1931	10A → 22Q	- 41.3663	+ .0050
			Sum + 3.3921 m =	+186.5800	+0.0025
			Orthometric height =	+186.5800	+0.0025
			=	186.5825	

Notes:

1/ This elevation difference is based on a proration of the results of both the 1926/1927/1928 and early 1961 levelings between Tidal 8, San Pedro, and E43, Barstow.

1926/1927/1928 = +640.2487 m

Early 1961 = +640.2307

Proration of the 0.0180-m subsidence of bench mark E43 during the interval 1926/1927/1928–1961 indicates that the 1938 observed elevation of this mark with respect to Tidal 8 was about 0.0058 m less than its 1926/1927/1928 observed elevation (i.e., 640.2429 m), and it is this computed value for E43 that has been used in this reconstruction.

TABLE 41. 22Q via Los Angeles, Saugus, Palmdale
1978 Mojave, Barstow, Amboy and Freda Junction

Route	Source	Dates of leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Pedro area	L-24301.1	1-5/1978	T8 → 21-03269	+ 8.8482	+0.0002
San Pedro → Mojave	L-24301.6	1-4/1978	21-03269 → Q49	+835.5896	+ .0423
Mojave → Barstow	L-24301.13	1-4/1978	Q49 → Gag Stn.	-203.6716	- .0192
Barstow → Amboy	L-24301.23	1-4/1978	Gag Stn. → T1250	-458.7536	- .0225
Amboy → Freda Jct.	L-24301.28	1-4/1978	T1250 → 10M	+ 79.4604	+ .0068
Freda Jct. → 20 W	L-24077	4-5/1976 1/	10M → 20W	+ 35.0718	+ .0022
20 W → 21 N	L-24085	9-10/1975 1/	20W → 21N	+ 7.0468	+ .0008
21 N → 220	L-24068	5-6/1976 1/	21N → 22Q	-120.4695	- .0065
			Sum + 3.3921 m =	+186.5142	+0.0041
			Orthometric height =	+186.5142	+0.0041
			=	186.5183	

Notes:

1/ Comparison of the results of 1978 leveling against a 1976 datum between Freda Junction and Amboy (NGS lines L-24077, L-24301.28) indicate that this reach remained free of differential movement during the period 1976-1978. Hence, the results of the 1975/1976 levelings between Freda Junction and 22Q are taken as the equivalent of those that would have been obtained in 1978.

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